stalling this process is high, and bears a large proportion to the market value of the annual production.

It follows, therefore, from these conclusions that the industrial demand for nitric acid in the future will probably be met by means of synthetic processes. It is conceivable that the marketing of large quantities of synthetic sulphate of ammonia and cyanamide, made in Germany, will influence the future price of combined nitrogen, and may even control it. The Committee thinks that the producers of combined nitrogen may eventually have to face a competitive price of 7*l.* or 8*l.* per metric ton for ammonium sulphate, and 6*l.* or 7*l.* per metric ton for cyanamide. The by-product ammonia industry in this country may thus be seriously menaced. It can scarcely recoup itself by raising the price of the other by-products to any serious extent, and considering the relation of combined nitrogen to the food of the country, public opinion, whilst willing to tolerate, up to a certain extent, the protection of "key" industries, would strongly resent any action which seriously interfered with the productive capacity of the land.

(*To be continued.*)

THE MICROSCOPY OF METALS.

At the very successful symposium on the microscope organised by the Faraday Society on January 14 in the rooms of the Royal Society, about one-half of the papers presented dealt with the microscopical examination of metals, a striking indication of the importance which this branch of microscopy has now acquired. It was therefore appropriate that the president, himself a distinguished worker in this field, should deal historically with the development of micro-metallography, as well as contributing an original paper to the discussion. Sir Robert Hadfield's introductory address surveyed the history of microscopical invention, and was illustrated by portraits of some of the pioneers in the art—Jansen, Lipperhey, Leeuwenhoek, Sorby, and Dallinger. We were reminded of the fact that, so far back as 1665, Robert Hooke described in his "Micrographia" the appearance of the point of a needle and the edge of a razor, and his faithful drawings of these two objects, revealing most accurately the features which could be observed under a low magnification, are reproduced in the paper. The next instance of the application of the microscope to the examination of metals is that by Réaumur, whose work on steel, published in 1722, contains many drawings of the magnified fractures of iron and steel bars. Such a method, however, gave little information, and did not lead to any further development. In 1808 Widmanstätten studied the structure of meteoric irons by polishing a plane section and heating until the constituents became differentially coloured by oxidation, thus introducing the method now familiar as "heat-tinting." The structure of these irons is so coarse that magnification is unnecessary, but the method gave hints to later workers, of whom Sorby is the chief. The work of Sorby, in view of its great importance, was dealt with by the president in a separate note.

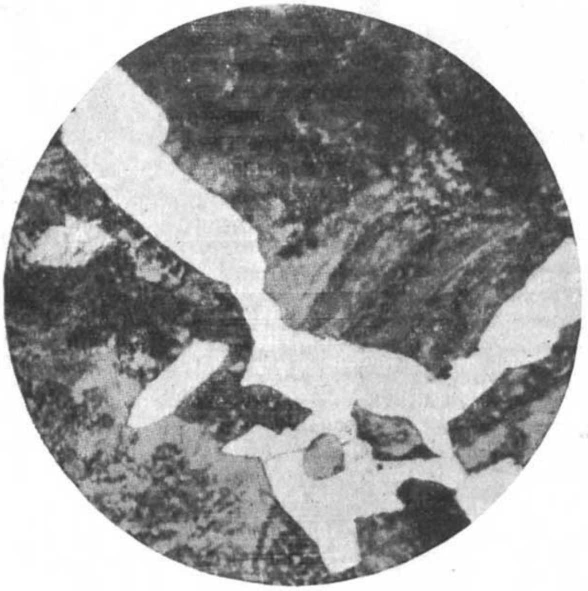

Fig. 1.—Magnification 600. 12 mm. Achromat.

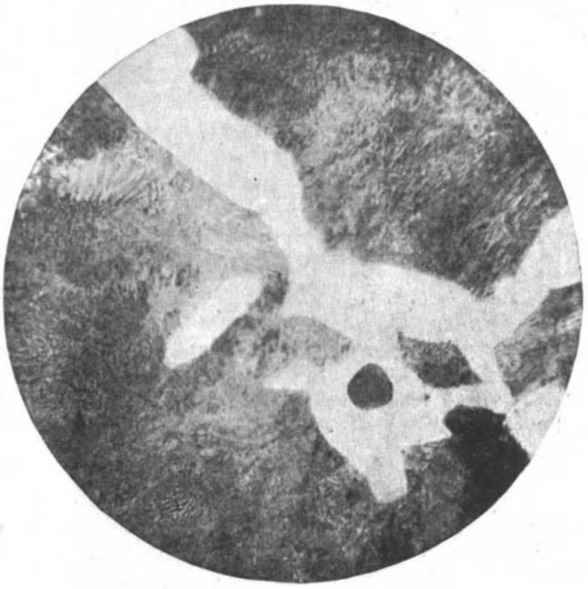

Fig. 2.—Magnification 600. 2 mm. Apochromat.

Phot micrographs showing the effect of magnification without resolution The steel used in this experiment had the following composition: C 0·48, Si 0·17, S 0·029, P 0·034, Mn 1·00 per cent.

Henry Clifton Sorby, one of those amateur scientific investigators who have contributed so wonderfully to the progress of science in this country, was led to devise the modern method of microscopic petrography by seeing sections of bone, teeth, etc., rendered transparent by affixing one surface to glass and then grinding down to an extreme thinness, as practised by the botanist Williamson. Sorby treated rocks in the same way, and in 1849 he prepared the first rock slice ever made. By 1851 he had become expert in the new process, and was able to publish his observations of the microscopic structure of limestones. In 1857 he presented to the Geological Society his famous paper on the fluid inclusions in quartz crystals, in which he ventured to draw conclusions as to the conditions under which rocks had been formed in Nature from the examination of the minute quantities of liquid enclosed in the microscopic cavities in crystals. The paper was received without enthusiasm, and even with ridicule, so absurd did it seem to study geological problems on the minute scale of the microscope. Nevertheless, Sorby's conclusions came to be accepted by all geologists, and his paper is now accepted as one of the classics of the science. In 1863 he turned his attention to iron and steel, being led to their study by an examination of meteorites. Just as he had fused masses of silicates artificially in an attempt to solve some of the problems connected with igneous rocks, so he proposed to use the information to be derived from artificial masses of iron and steel for the explanation of the characteristics of meteoric irons. He exhibited sections of iron and steel, and photographs taken from them, at Sheffield and also at the Bath meeting of the British Association in 1864, and even these early photographs, taken, of

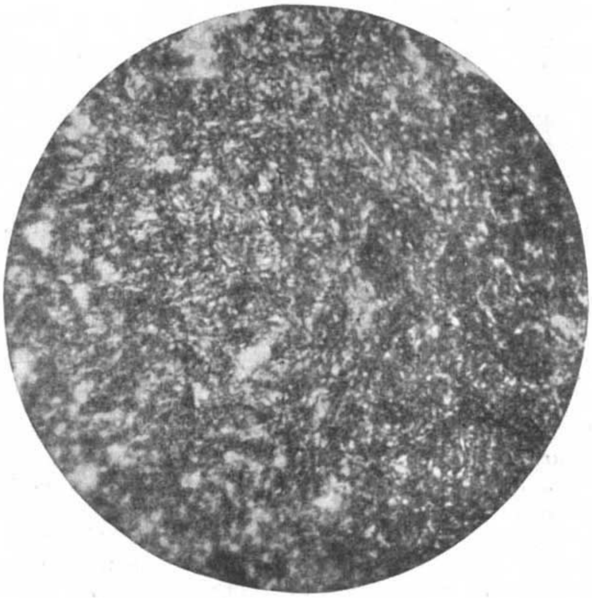

FIG. 3.—Magnification 100.

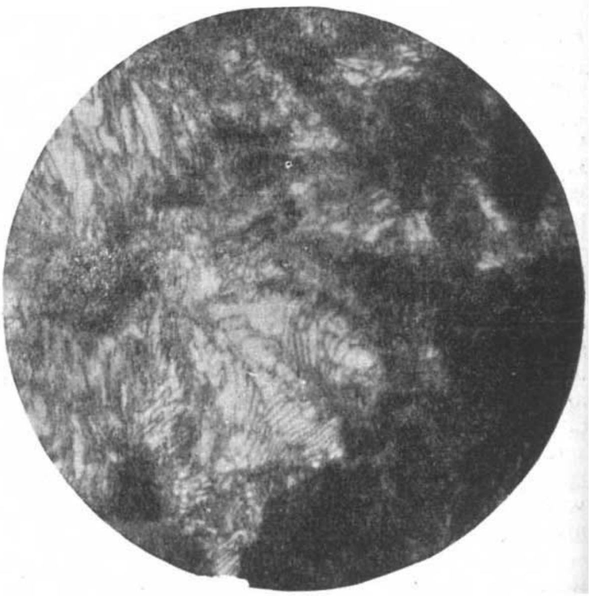

FIG. 4 Magnification 1500.

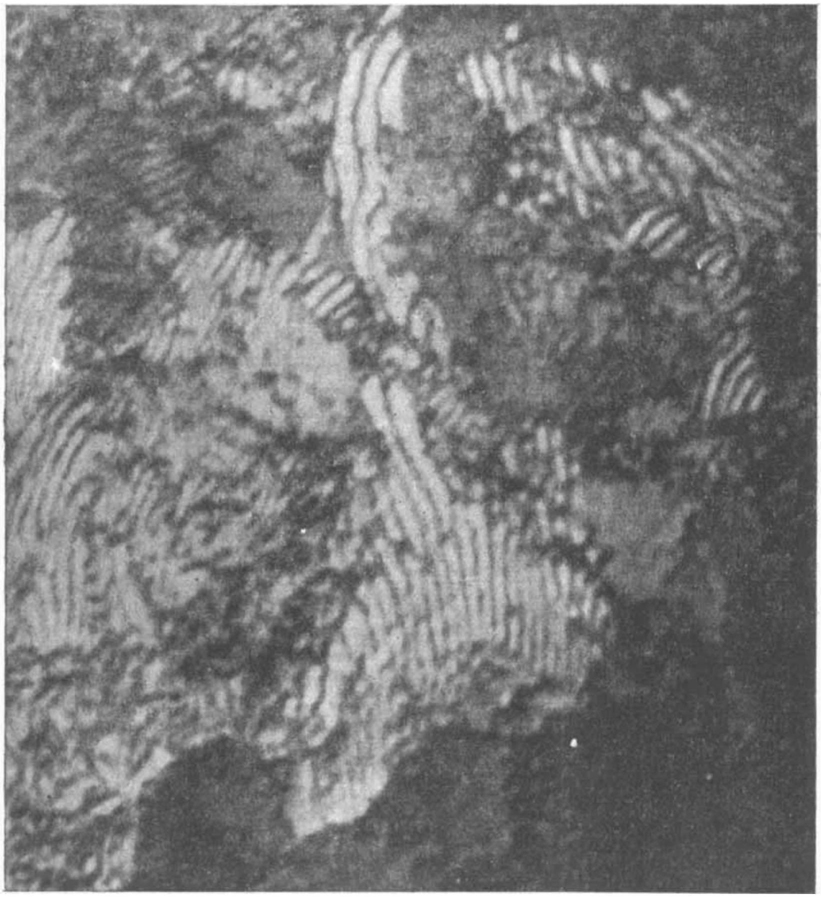

FIG. 5.—Magnification 5000.
2 mm. Apochromat. Structure of fine lamellar and sorbitic pearlite. The steel used in this experiment had the following composition: C 0·84, Si 0·30, Mn 0·45, Cr 1·12, Ni 0·12 per cent.

course, at low magnifications, leave little to be desired in regard to sharpness and beauty. A collection of Sorby's original polished and etched sections of metals is carefully preserved by the University of Sheffield, and was lent on the occasion of the symposium.

Sorby's discovery aroused little interest, and when, in 1877, Prof. Martens, of Berlin, soon followed by Osmond and by Le Chatelier in Paris, began the study of metals with the aid of the microscope, the work of their predecessor had been forgotten. By this time, however, a general interest in the subject had been awakened, and Sorby's important papers in the Journal of the Iron and Steel Institute in 1886 and 1887 met with a more appreciative audience. By employing higher magnifications, Sorby was able to show that the "pearly constituent" of steel, as he had called one of its principal constituents, owing to the mother-of-pearl lustre often exhibited by it, was in reality an aggregate of parallel plates of a soft and a hard material. This discovery placed the metallography of steel on a firm basis, and prepared the way for the complete explanation of its structure when thermal methods were added to those of the microscope. Great as were the services of other investigators, it is to Sorby that we owe, without question, our modern metallographic methods.

Sorby laid great stress on the extension of our knowledge by the use of higher magnifying powers, so well illustrated by his own discovery of the true nature of pearlite. Most metallographic work is done at magnifications not exceeding 500 diameters, but excellent results have been obtained by some workers with magnifications of 1000 and even of 1500 diameters. The minuteness of many metallic structures, especially those of hardened and tempered steels, has made many metallographers wish for a means of applying much higher magnifications. Since the discovery of new detail depends, not on the magnifying power, but on the resolving power of the microscope, it is necessary to increase the latter. This may be effected either by increasing the numerical aperture of the objective, or by shortening the wave-length of the light used for illumination. The numerical aperture can be increased beyond its present maximum only by the use of other materials than glass, a plan which is likely to be adopted at some future time, whilst the use of ultra-violet light, the magnificent results of which in bacteriology were shown at the meeting by Mr. J. E. Barnard, has so far given disappointing results with metals.

A valuable contribution to the study of highly magnified metal sections was made by the third paper under notice, that by Sir Robert Hadfield and Mr. T. G. Elliot. The numerous and very beautiful plates illustrate both the advantages of high magnifications and the pitfalls which have to be avoided if success is to be obtained. For example, a field containing ferrite and pearlite is shown in three photographs, all taken at a magnification of 600 diameters, but with objectives of different resolving power. With a 12-mm. objective, the pearlite is structureless (Fig. 1), and only when a 2-mm. apochromat is used is its minute lamination fully revealed (Fig. 2). Another pearlite has its structure revealed at 1500 diam. (Fig. 4), but becomes much clearer at 5000 (Fig. 5), using the same objective. No further advantage is shown at 8000 diam. The effect of narrowing the aperture too much is shown by the apparent broadening of the cementite lamellæ in the pearlite, the true breadth being seen very clearly when the iris diaphragm is opened sufficiently. The photographs, all of which are remarkably good, may be said to be most successful in the case of pearlitic structures. The structure of martensite at 5000 diam. is not so clearly seen as at a much lower magnification, whilst the minutely granular structures of troostite and sorbite evidently call for a higher resolving power rather than for mere enlargement to indicate their true nature. The paper will serve a most useful purpose in directing attention to the nature of the problem, and perhaps attracting skilled optical workers and physicists to its solution.

C. H. D.

REPORT OF THE CALCUTTA UNIVERSITY COMMISSION.[1]

At first sight a report in five volumes, each of upwards of four hundred pages, on the Calcutta University Commission would appear somewhat portentous; but anyone alive to the importance of university education in India who makes a study of these volumes will be quickly reconciled to their length and number. For it may be fairly claimed that they contain scarcely a sentence which one would desire to see omitted. The whole report of the Commission, including evidence and appendices, comprises no fewer than thirteen volumes, but we are here concerned only with the first five. Vols. i., ii., and iii. contain a very masterly analysis of the present conditions of education obtaining in Bengal, and vols. iv. and v. the actual recommendations of the Commission.

Although this report ostensibly deals only with education in Bengal, the greater part of it naturally has bearing on our educational systems throughout India. The whole report is a model of style, and bears testimony to the infinite pains and care taken by its editors. The names of the members of the Commission were a sufficient guarantee of its thoroughness and accuracy. The review of the present conditions of education in Bengal constitutes in itself one of the most valuable documents for the student of British rule in India. Reports, annual and quinquennial, have been issued in quantity from the various secretariats in India, but we know of nothing to compare for thoroughness and instructiveness with the chapters under review.

It is, of course, impossible for us in this place to do more than refer briefly to one or two of

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[1] Reports of the Calcutta University Commission, 1917-19. (Calcutta Superintendent Government Printing, India, 1919.) Prices: Vol. i., Part i. 3s.; Vol. ii., Part i., 3s. 6d.; Vol. iii., Part i., 1s. 6d.; Vol. iv., Part ii., 2s 6d.; Vol. v., Part ii., 2s.